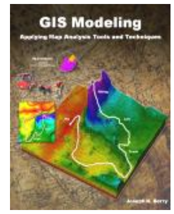
Beyond Mapping IV

Topic 10 – Future Directions and Trends (Further Reading)



GIS Modeling book

From a Map Pancake to a Soufflé — *continues the discussion of concepts and configuration of a 3D GIS (December 2009)*

<*Click here*> *for a printer-friendly version of this topic (.pdf).*

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From a Map Pancake to a Soufflé

(GeoWorld, December 2009)

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As the Time Traveller noted in H. G. Wells' classic "The Time Machine," the real world has three geometric dimensions not simply the two we commonly use in mapping. In fact, he further suggested that "...any real body must have extension in four directions: Length, Breadth, Thickness—and Duration (time)" …but that's a whole other story.

Recall from earlier discussion of 3D GIS that *Geodetic Referencing* (geographic position) used in identifying an "areal extent" in two-dimensions on the earth's surface can be extended to a *Database Referencing* system (matrix location) effectively defining a 3-dimensional "project block" (see the left side of figure 1). The key is the use of *Geodetic Height* above and below the earth's ellipsoid as measured along the perpendicular from the ellipsoid to provide the vertical (Z) axis for any location in 3-dimensional space.

The result is a coordinate system of columns (X), rows (Y), and verticals (Z) defining an imaginary matrix of grid elements, or "voxels," that are a direct conceptual extension of the "pixels" in a 2D raster image. For example, the top-right inset in figure 1 shows a 3D map of a cave system using ArcGIS 3D Analyst software. The X, Y and Z positioning forms a 3-dimensional display of the network of interconnecting subterranean passages. The lower-right inset shows an analogous network of blood vessels for the human body except at much different scale. The important point is that both renderings are 3D visualizations and not a 3D GIS as they are unable to perform volumetric analyzes, such as directional flows along the passageways.

The distinction between 3D visualization and analytical systems arises from differences in their data structures. A 3D visualization system stores just three values—X and Y for "where" and Z for "what (elevation)." A 3-dimensional mapping system stores at least four values—X, Y and

Z for “where” and an attribute value for “what” describing the characteristic/condition at each location within a project block.

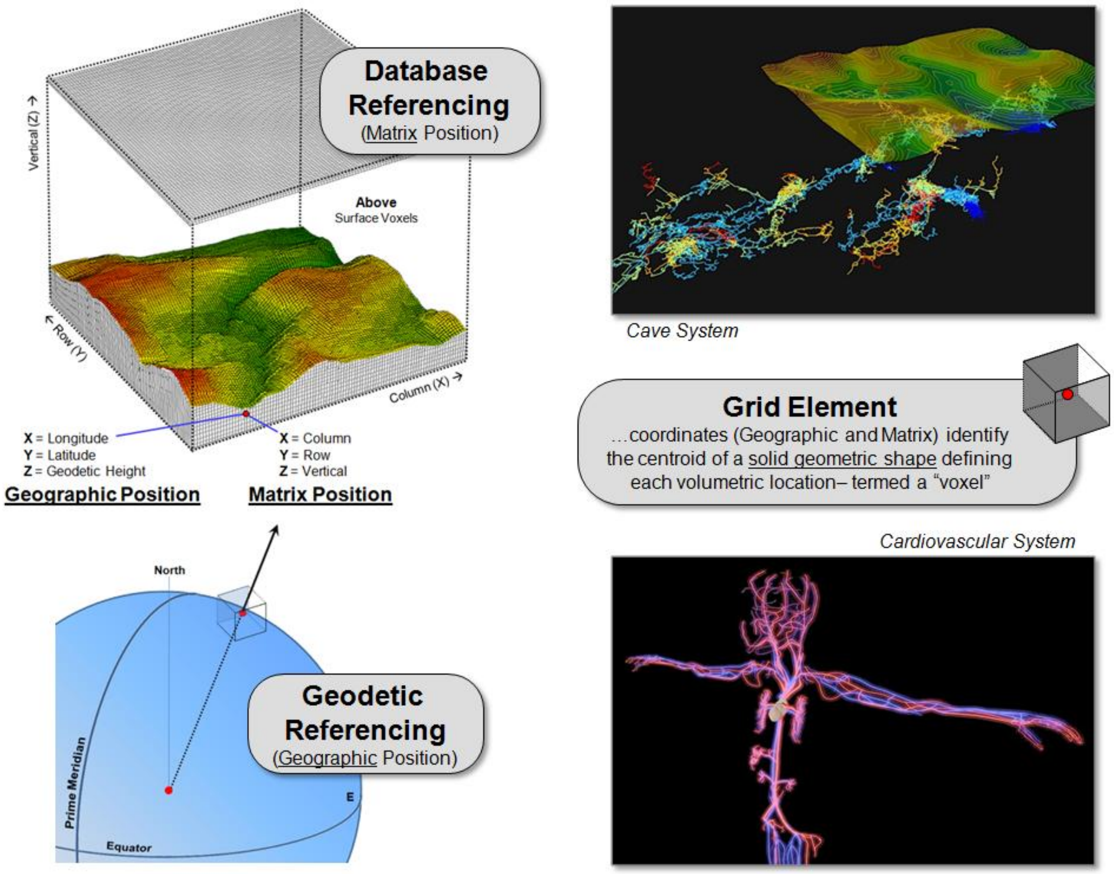
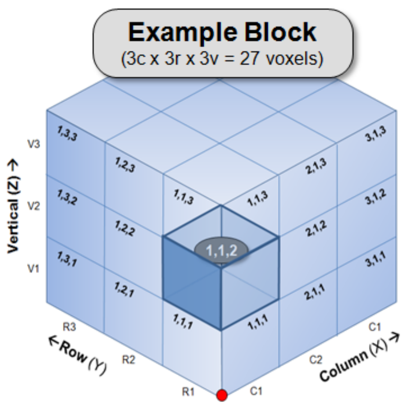


Figure 1. Storage of a vertical (Z) coordinate extends traditional 2D mapping to 3D volumetric representation.

Figure 2 illustrates two ways of storing 3-dimensional grid data. A *Flat File* stores a single map value for each grid element in a map block. The individual records can explicitly identify each grid element (grayed columns—“where”) along with the attribute (black column—“what”). Or, much more efficiently, the information can be implicitly organized as a header line containing the grid block configuration/size/referencing followed by a long string of numbers with each value’s position in the string determining its location in the block through standard nested programming loops. This shortened format provides for advanced compression techniques similar to those used in image files to greatly reduce file size.

An alternative strategy, termed an *Interleaved File*, stores a series of map attributes as separate fields for each record that in turn represents each grid element, either implicitly or explicitly organized into a table. Note that in the interleaved file in figure 2, the map values for Elevation, %Slope and Cover type identify surface characteristics with a “null value (---)” assigned to grid elements both above and below the surface. Soil type, on the other hand, contains values for the grid elements on and immediately below the surface with null values only assigned to locations above ground. This format reduces the number of files in a data set but complicates compression and has high table maintenance overhead for adding and deleting maps.



A **Flat File** stores a single attribute for each grid element of a map block.

An **Interleaved File** stores information as a multiple record with separate fields in a table for each attribute within a grid element of a map block.

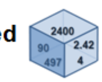
The geographic/matrix positioning for the grid elements can be **Explicitly** stored with the map value(s) record; or **Implicitly** inferred by the systematic ordering of the records, usually row/column major looping in the record string.

Flat File

Elevation= 2400ft

Obj #	Row (Y)	Col (X)	Vert (Z)	Value Elevation
1	1	1	1	---
2	1	1	2	2400
3	1	1	3	---
4	1	2	1	---
5	1	2	2	---
6	1	2	3	2404
7	1	3	1	---
8	1	3	2	---
9	1	3	3	2409
10	2	1	1	---
11	2	1	2	2400
12	2			
13	2			
14	2			
15	2			
16	2			
17	2			
18	2			
19	3			
20	3			
21	3			
22	3			
23	3			
24	3			
25	3			
26	3			
27	3			

Interleaved File



Elevation= 2400ft
Slope= 2.42%
Cover Type= 4
Soil Type= 497

Obj #	Row (Y)	Col (X)	Vert (Z)	Value Elevation	Value % Slope	Value Cover	Value Soil
1	1	1	1	---	---	---	497
2	1	1	2	2400	2.42	4	497
3	1	1	3	---	---	---	---
4	1	2	1	---	---	---	497
5	1	2	2	---	---	---	497
6	1	2	3	2404	4.58	4	497
7	1	3	1	---	---	---	497
8	1	3	2	---	---	---	497
9	1	3	3	2409	3.81	4	497
10	2	1	1	---	---	---	497
11	2	1	2	2400	2.17	4	497
12	2	1	3	---	---	---	---
13	2	2	1	---	---	---	497
14	2	2	2	---	---	---	497
15	2	2	3	2404	5.44	4	497
16	2	3	1	---	---	---	497
17	2	3	2	---	---	---	497
18	2	3	3	2409	9.86	4	497
19	3	1	1	---	---	---	497
20	3	1	2	2401	3.25	4	497
21	3	1	3	---	---	---	---
22	3	2	1	2399	2.16	3	497
23	3	2	2	---	---	---	---
24	3	2	3	---	---	---	---
25	3	3	1	---	---	---	497
26	3	3	2	2403	5.22	3	497
27	3	3	3	---	---	---	---

Figure 2. A 3-dimensional matrix structure can be used to organize volumetric mapped data.

Figure 3 outlines some broader issues and future directions in 3D GIS data storage and processing. The top portion suggests that the inconsistent geometry of the traditional *Cube* results in differing distances and facet adjacency relationship to the surrounding twenty six neighbors, thereby making a cube a poor grid element for 3D data storage. A *Dodecahedron*, on the other hand, aligns with a consistent set of 12 equidistant pentagonal faces that "nest" without gaps ...an important condition in spatial analysis of movements, flows and proximal conditions.

The lower portion of figure 3 illustrates the knurly reality of geographic referencing in 3-dimensions—things change as distance from the center of the earth or bounding ellipsoid changes. Nicely nesting grid elements of a fixed size separate as distance increases (diverge); overlap as distance decreases (converge). To maintain a "close-packing" arrangement either the size of the grid element needs to adjust or the progressive errors of fixed size zones are tolerated.

Similar historical changes in mapping paradigms and procedures occurred when we moved from a flat earth perspective to a round earth one that generated a lot of room for rethinking. There are likely some soon-to-be-famous mathematicians and geographers who will match the likes of

Claudius Ptolemy (90-170), Gerardus Mercator (1512-1594) and Rene Descartes (1596-1650)—I wonder who among us will take us beyond mapping as we know it?

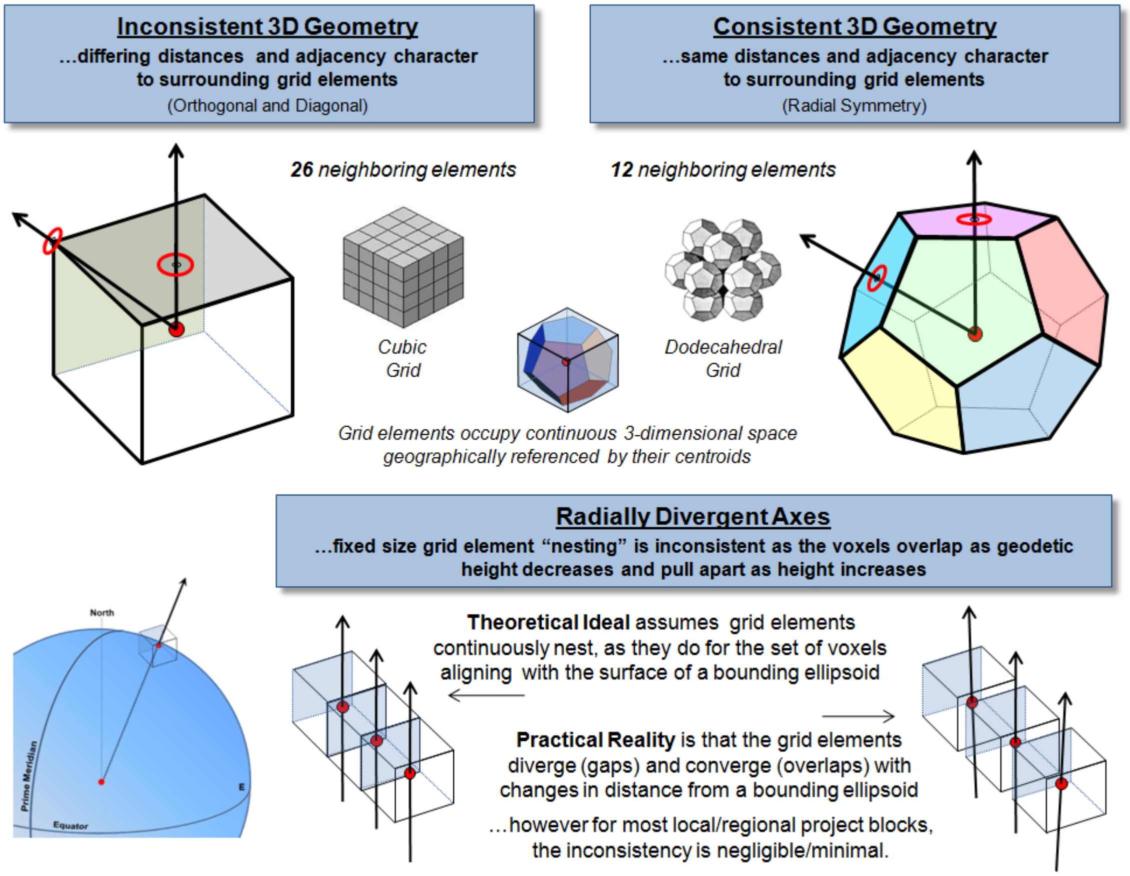


Figure 3. Alternative grid element shapes and new procedures for dealing with radial divergence form the basis for continued 3D GIS research and development.

Author's Notes: *A good discussion of polyhedral and other 3-dimensional coordinate systems is in Topic 12, "Modeling locational uncertainty via hierarchical tessellation," by Geoffrey Dutton in Accuracy of Spatial Databases edited by Goodchild and Gopal. In his discussion he notes that "One common objection to polyhedral data models for GIS is that computations on the sphere are quite cumbersome … and for many applications the spherical/geographical coordinates … must be converted to and from Cartesian coordinates for input and output."*

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